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Effect of Ohmic Heating on the Quality and Stability of Carrot and Orange Juice Blend

Esha Afzal, Fatima Waheed, Maryam Tufail Chaudhary and Ali Hassan*

National Institute of Food Science and Technology, University of Agriculture Faisalabad, Pakistan.
*Corresponding author's e-mail: ali_ft32@yahoo.com

Carrots (*Daucus carota*) and oranges (*Citrus cinensis*) are widely consumed in raw form but blending these commodities in the form of juice blend enhances their palatability and boosts their nutritional value. Conventional heating poses challenges such as nutrition loss and uneven heating while ohmic heating being a novel and efficient technique, employs an electric current to ensure rapid and uniform heating. This study aimed to examine the effectiveness of ohmic heating on safety and quality parameters during storage period of juice blend. Seven different treatments were applied including T_0 (Control), T_1 (100 V and 300 s), T_2 (100 V and 450 s), T_3 (100 V and 600 s), T_4 (120 V and 300 s), T_5 (120 V and 450 s) and T_6 (120 V and 600 s). Physicochemical, phytochemical, microbial and sensory evaluation were determined, and storage study of 2 weeks was conducted to check the safety and nutritional quality of the juice blend. The results showed that the lowest pH was 4.31±0.1 for T_6 at 0-day, highest total titratable acidity was 0.72±0.02 for T_6 at 0-day, highest total soluble solids were 13.0±0.2 for T_6 at 14-day, highest color values were observed for T_0 and highest vitamin C values were 4.18±0.26 for T_0 at 0 day. The highest total phenolic content was 27.81±0.24 for T_6 at 0 day. The lowest total plate count (0.86±0.02) and total coliform count (4.77±0.15) were observed for T_6 at 0 day. The best treatment was T_6 with lowest total plate and total coliform count, enhanced the quality attributes of juice blend and had the best sensory acceptability. Thus, indicated that ohmic heating is the best treatment to enhance the quality and shelf life of juice blend alternative to conventional heating.
Keywords: Refresh mix, energy efficiency, nutrition retention, market fit and future advocacy.

INTRODUCTION

Carrot (*Daucus carota*) is a popular root plant that is grown all over the world and it is the most leading crop in the *Apiaceae* family (Karangwa et al., 2012). Carrot is a common vegetable that is high in flavonoids, phenolics, fibers, polyacetylenes, vitamins C, vitamin E, carotenoids and minerals. Plants high in phenolic compounds are beneficial in decreasing the risk of different metabolic diseases and act as antioxidants (Potter et al., 2011). Along with other benefits, carrots also help in wound healing, maintaining liver health, preventing from diabetes and hypertension (Singh et al., 2021).

Orange (*Citrus cinensis*) is a popular crop grown widely and is regarded as a rich source of vitamin C (Karangwa et al., 2012). It contains naringin, carotenoids, cyanidin glucoside, firulic acid, citric acid, vitamin C and vitamin H, so, they are beneficial in reducing the symptoms of chronic heart diseases and asthma (Rawal et al., 2023). Blending makes a highly nutritious beverage with great taste. Juice blend can be made by blending two or more fruit and vegetables in different ratios. It makes an innovative and nutrient rich product as consumers look for healthier options (Hussein et al., 2022).

Water activity, competing microflora, pH, presence of antimicrobial compounds and oxidation reduction potential are important factors that affect the shelf life of juice. The two most important variables influencing decline in juice quality are pH and water activity (Aneja et al., 2014).Heat treatments are linked with quality depletion of juice because heating destroys the heat sensitive vitamins and aroma. For example, carotenoids are sensitive to chemical exposure, light and temperature during processing (Achir et al., 2016).

However, the conventional heating (CH) methods such as radiation, conduction and convection have a high heat transfer rate. Therefore, CH causes the outer layer to overheat, resulting in loss of nutrients (Doan et al., 2023).Apart from conventional heating, the novel heat treatment including ohmic heating is currently gaining popularity and is being used in food industries because it ensures better thermal efficiency. Thus, creates an internal heat due to an electrical

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resistance, a phenomenon called as "Joule effect". A uniform temperature distribution is produced which is particularly beneficial for liquid foods with high electrical conductivity(Achir et al., 2016).

Ohmic heating is used for different purposes including aseptic processing, thawing, extraction, fermentation, blanching, pasteurization and sterilization (Jan et al., 2021). OH is more efficient as compared to CH due to the presence of electric field which inactivates the enzymes and microorganisms more quickly (Doan et al., 2023). The main objectives of this research included to check the effectiveness of ohmic heating treatment on safety and quality attributes of juice blend and to check the impact of ohmic heating on shelf-life extension of juice blend.

MATERIALS AND METHODS

***Procurement of raw material*:** Carrots and oranges were procured from the local market of Faisalabad.

***Carrot-orange juice blend preparation*:** The carrots and oranges were washed and then dried to remove dirt and debris. After peeling off oranges, each section was separated, and the seeds were removed. The carrots were also peeled off and cut into chunks. The juice was obtained by pressing carrots and oranges using a household juicer. Both juices were combined in 50:50 ratio (v/v) to create a juice blend.

***Ohmic heating process*:** The ohmic heating process was used to evaluate the safety and quality parameters of blend. By applying an electric current, heat was generated inside the juice blend within the OH chamber. To study the effect of OH on juice blend, seven different treatments were applied as mentioned in Table 1.

Table 1. Treatment plan of ohmic heating process.

Treatment	Voltage (V)	Time (s)
T_0	-	-
T_1	100	300
T_2	100	450
T_3	100	600
T_4	120	300
T_5	120	450
T_6	120	600

Note: The storage study of 2 weeks was done at an interval of 0, 7 and 14 days.

Physicochemical Analysis of Juice Blend

***Total Titratable Acidity (TTA)*:** Total Titratable Acidity (TTA) of juice blend was assessed using the protocols followed by AOAC (2023).

***Total Soluble Solids (TSS)*:** Total Soluble Solids (TSS) of juice blend was determined using the procedure followed by AOAC (2023).

***pH*:** The pH of juice blend was assessed by using pH meter followed by AOAC (2023).

***Color*:** Color of juice blend was determined using the colorimeter with slight modification (AOAC, 2023).

***Vitamin C Determination*:** Vitamin C content of juice blend was assessed using the method of Esteve and Frigola (2008). 2,6-dichlorophenol indophenol was used as an indicator.

Phytochemical Analysis of Juice Blend

***Total Phenolic Content (TPC)*:**

Total phenolic content of juice blend was determined using the method of Esteve and Frigola (2008). Absorbance of sample was detected using spectrophotometer at a wavelength of 760 nm and gallic acid was used as a standard reagent to determine the TPC of juice blend.

Microbial Count

***Total Plate Count (TPC)*:** The method of Asghar *et al.* (2018)was used to estimate the total plate count (TPC) of juice blend. The CFU per mL was calculated using an appropriate formula.

***Total Coliform Count (TCC)*:** The method of Asghar *et al.* (2018) was used to determine the total coliform count (TCC) of juice blend. It was also calculated in CFU per mL.

***Sensory Evaluation*:** Sensory evaluation of juice blend was done using the 9-point hedonic scale (Adubofuor et al., 2016).

RESULTS

***pH*:** The calculated pH 4.31±0.1-5.01±0.05 showed the highly significant effect of treatments during the whole storage study. A slightly decreasing trend was observed in treatments with varied voltage and time. The maximum value of pH was noticed in control treatment T_0 (5.01±0.05) after 14 days followed by treatment T_1 (4.81±0.06) after 14 days. The minimum value of pH at 0 day was observed in treatment T_6 (4.31±0.1). The highest observation was recorded at 14 days of duration, whereas the value of pH observed at 7 days was lower. The above findings ultimately showed that T_6 (120 V and 600 s) has the lowest pH and is considered as the best treatment because low pH and high acidity inhibits the growth of microbes.

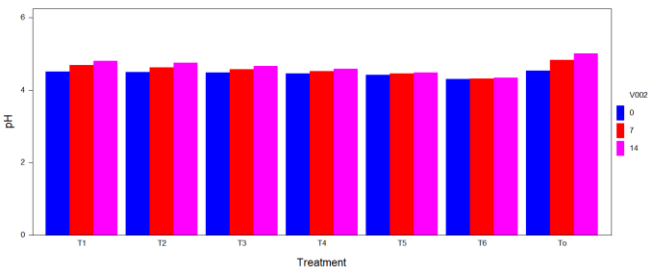

Figure 1. Effect of Ohmic Heating on pH of Carrot and Orange Juice Blend.

***Total Titratable Acidity*:** The lowest values of TTA were noticed for the control treatment at 14 day (0.22±0.07), whereas treatment T_1 had a TTA value of 0.25±0.02 at 14 day.

The maximum obtained value for TTA was recorded for treatment T_6 at 0 day 0.72±0.02 which was the best treatment and retained during the storage period 0.61±0.02 due to which shelf life of blend increases. The duration of days had shown a decreasing trend in titratable acidity. The above findings ultimately showed that T_6 (120 V and 600 s) has the lowest pH and is considered as the best treatment because high acidity enhances the flavor and preserves the juice by inhibiting microbial growth.

***Total Soluble Solids*:** The TSS gradually increased with increasing voltage and time. The highest value of TSS (13.0±0.2) was recorded in T_6 treatment at 14th day. Whereas the lowest value of TSS (10.3±0.3) was recorded in T_0 treatment at 0 day. The above findings ultimately showed that T_6 (120 V and 600 s) has the highest TSS which means that the ohmic heating had a highly significant effect on the TSS of juice blend.

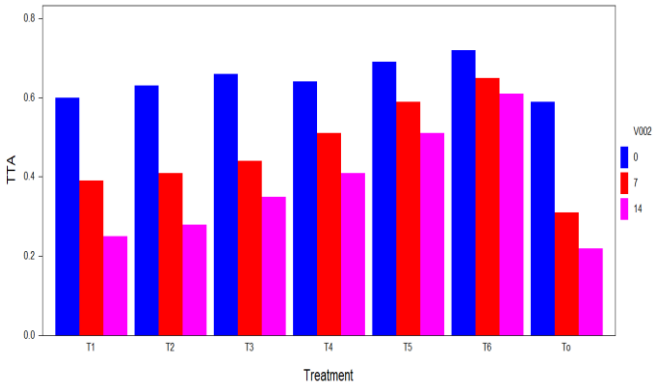

Figure 2. Effect of Ohmic Heating on TTA of Carrot and Orange Juice Blend.

Table 2. Means for Physicochemical Analysis of Carrot and Orange Juice Blend.

	Treatments	Storage Intervals (Days)			
		0 days	7 days	14 days	Means
pH	T_0	4.53±0.41	4.83±0.09	5.01±0.05	4.790±0.29^{A}
	T_1	4.51±0.22	4.69±0.19	4.81±0.06	4.670±0.19^{AB}
	T_2	4.50±0.06	4.62±0.32	4.75±0.04	4.623±0.19^{AB}
	T_3	4.48±0.21	4.57±0.07	4.67±0.02	4.573±0.13^{ABC}
	T_4	4.46±0.18	4.52±0.24	4.59±0.02	4.523±0.16^{ABC}
	T_5	4.42±0.31	4.46±0.29	4.48±0.01	4.453±0.21^{BC}
	T_6	4.31±0.10	4.32±0.06	4.34±0.05	4.323±0.06^{C}
	Means	4.46±0.07^{A}	4.57±0.16^{AB}	4.66±0.22^{B}	
Titratable acidity (%)	T_0	0.59±0.04	0.31±0.11	0.22±0.07	0.373±0.18^{E}
	T_1	0.6±0.03	0.39±0.1	0.25±0.02	0.413±0.16^{DE}
	T_2	0.63±0.06	0.41±0.07	0.28±0.06	0.440±0.16^{CDE}
	T_3	0.66±0.03	0.44±0.05	0.35±0.04	0.483±0.14^{CD}
	T_4	0.64±0.07	0.51±0.01	0.41±0.08	0.520±0.11^{BC}
	T_5	0.69±0.02	0.59±0.03	0.51±0.06	0.596±0.08^{AB}
	T_6	0.72±0.02	0.65±0.05	0.61±0.02	0.660±0.05^{A}
	Means	0.65±0.04^{A}	0.47±0.11^{B}	0.38±0.14^{C}	
Total soluble solids (°Brix)	T_0	10.3±0.3	10.4±0.2	10.6±0.2	10.433±0.24^{D}
	T_1	10.5±0.4	10.7±0.4	10.9±0.1	10.700±0.33^{CD}
	T_2	10.7±0.2	10.9±0.2	11.0±0.1	10.867±0.21^{C}
	T_3	10.6±0.4	10.8±0.3	11.0±0.3	10.800±0.33^{CD}
	T_4	10.8±0.1	11.5±0.4	12.1±0.1	11.467±0.60^{B}
	T_5	11.1±0.3	11.7±0.3	12.5±0.1	11.757±0.64^{B}
	T_6	11.7±0.2	12.5±0.3	13.0±0.2	12.400±0.60^{A}
	Means	10.84±0.73^{C}	11.21±0.89^{B}	11.59±0.93^{A}	
Vitamin C	T_0	4.18±0.26	3.26±0.39	1.57±0.20	3.003±1.17^{A}
	T_1	3.71±0.44	3.19±0.08	1.73±0.17	2.876±0.92^{AB}
	T_2	3.67±0.29	2.82±0.25	1.95±0.15	2.813±0.77^{AB}
	T_3	3.52±0.42	2.74±0.52	2.08±0.19	2.780±0.71^{AB}
	T_4	3.01±0.14	2.43±0.23	2.28±0.14	2.573±0.36^{B}
	T_5	2.85±0.21	2.51±0.26	2.36±0.06	2.573±0.27^{B}
	T_6	2.73±0.11	2.67±0.47	2.52±0.49	2.640±0.35^{AB}
	Means	3.38±0.53^{A}	2.80±0.31^{B}	2.07±0.34^{C}	

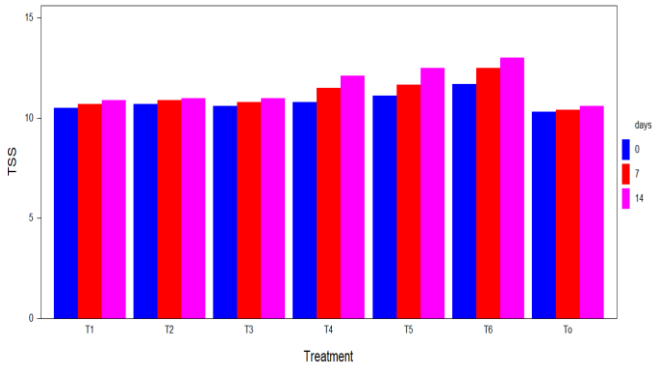

Figure 3. Effect of Ohmic Heating on TSS of Carrot and Orange Juice Blend.

***Vitamin C*:** The results in Table 2 showed the decreasing trend from 4.18±0.26-2.73±0.11 in mean values of vitamin C while increasing the voltages and time. But there was lowest decline observed in values of treatment T_6 (120 V and 600 s) during storage from 2.73±0.11 to 2.52±0.49 and same trend is seen in treatment T_5. The above findings ultimately showed that T_6 (120 V and 600 s) has the lowest value because vitamin C is heat sensitive, but less degradation occurred in storage due to ohmic heating than that of untreated sample.

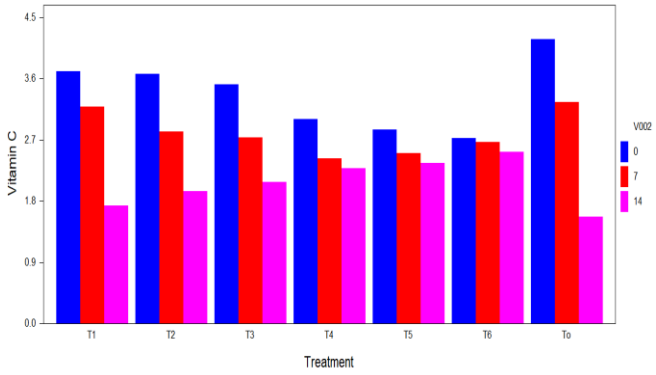

Figure 4. Effect of Ohmic Heating on Vitamin C of Carrot and Orange Juice Blend.

***Color*:** A decreasing trend in L* was observed in the storage of juice blend. The lowest observation of L* was measured in T_1 (100V and 300s) at 14th day of storage. But it was retained by the treatment T_6 during the storage from 33.72±0.13-33.04±0.08. The highest measured value of color (a*) was noticed in T_0 15.78±0.09 at 0 day followed by the treatment T_1 at 0 day 15.35±0.08. The lowest calculation of color (a*) was noticed in T_0on the 14th day. The a* value for T_6 decreased at 0 day from 15.78±0.09 to 12.18±0.17 but slight decrease was observed during storage 11.97±0.17 at 14th day as compared to control. The highest measured value of color (b*) was noticed in T_1 10.04±0.03 at 0 day followed by the treatment T_0 at 0 day 10.02±0.05. The b* value for T_6 decreased at 0 day from 10.04±0.03 to 8.74±0.03 but slight decrease was observed during storage 8.41±0.04 at 14thday as compared to control.

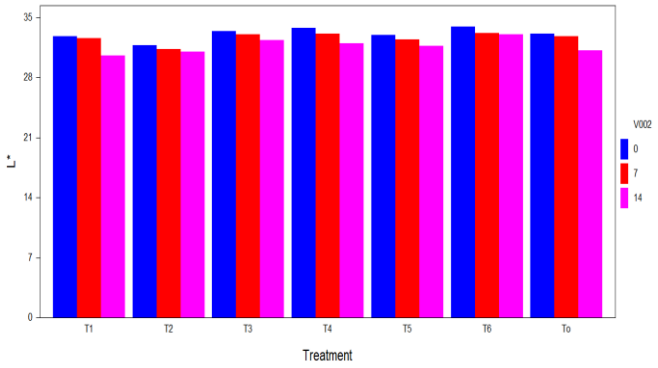

Figure 5. Effect of Ohmic Heating on L* of Carrot and Orange Juice Blend.

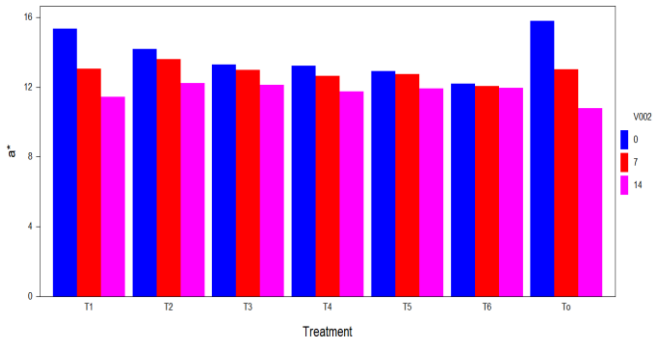

Figure 6. Effect of Ohmic Heating on a* of Carrot and Orange Juice.

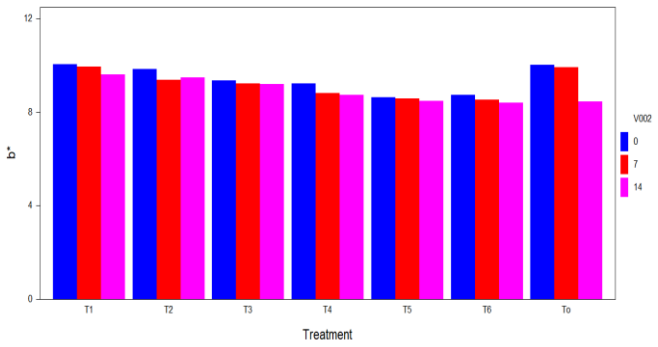

Figure 7. Effect of Ohmic Heating on b* of Carrot and Orange Juice Blend.

***Total Phenolic Content*:** The calculated value lies between 17.08±0.1-27.81±0.24 among the treatments during the whole storage period. An overall increasing trend was observed in juice blend with varied treatments of different voltage and time. The lowest values of total phenolic content were noticed for control treatment (17.08±0.1) at 14-day whereas treatment

Table 3. Means for Color of Carrot and Orange Juice Blend.

	Treatments	Storage Intervals (Days)			
		0 days	7 days	14 days	Means
L*	T_0	33.96±0.13	32.83±0.09	31.15±0.08	32.357±0.91^{C}
	T_1	32.85±0.24	32.59±0.12	30.59±0.13	32.010±1.08^{D}
	T_2	31.79±0.16	31.35±0.26	31.04±0.03	31.393±0.36^{E}
	T_3	33.43±0.14	33.04±0.05	32.36±0.21	32.943±0.48^{B}
	T_4	33.81±0.07	33.09±0.07	32.02±0.04	32.973±0.78^{B}
	T_5	32.96±0.13	32.45±0.27	31.72±0.12	32.377±0.56^{C}
	T_6	33.72±0.13	33.17±0.09	33.04±0.08	33.377±0.42^{A}
	Means	33.12±0.75^{A}	32.64±0.63^{B}	31.70±0.84^{C}	
a*	T_0	15.78±0.09	13.01±0.13	10.78±0.10	13.190±2.17^{A}
	T_1	15.35±0.08	13.05±0.07	11.46±0.03	13.287±1.69^{A}
	T_2	14.17±0.09	13.59±0.07	12.24±0.07	13.333±0.86^{A}
	T_3	13.29±0.18	12.98±0.02	12.14±0.07	12.803±0.52^{B}
	T_4	13.21±0.14	12.64±0.13	11.76±0.16	12.537±0.64^{C}
	T_5	12.93±0.15	12.73±0.04	11.92±0.17	12.527±0.47^{C}
	T_6	12.18±0.17	12.05±0.05	11.97±0.17	12.067±0.15^{D}
	Means	13.84±1.31^{A}	12.86±0.47^{B}	11.75±0.49^{C}	
b*	T_0	10.02±0.05	9.92±0.21	8.45±0.19	9.907±0.17^{A}
	T_1	10.04±0.03	9.95±0.12	9.61±0.14	9.867±0.21^{A}
	T_2	9.85±0.10	9.38±0.30	9.47±0.09	9.567±0.27^{B}
	T_3	9.36±0.18	9.23±0.07	9.21±0.15	9.267±0.14^{C}
	T_4	9.23±0.02	8.81±0.03	8.73±0.13	8.923±0.24^{D}
	T_5	8.63±0.15	8.57±0.09	8.49±0.21	8.563±0.14^{E}
	T_6	8.74±0.03	8.53±0.24	8.41±0.04	8.560±0.18^{E}
	Means	9.41±0.58^{A}	9.20±0.59^{B}	9.10±0.55^{B}	

T_1 had TPC value of 19.62±0.11 at 14 day. The maximum obtained value for total phenolic content of blend was recorded for treatment T_6 (27.81±0.24) at 0 day. The duration of days had shown a decreasing trend for total phenolic content of juice blend. At 14-day minimum decrease was measured for T_6 (26.83±0.07). The minimum value was recorded at 0-day where no treatment was applied. So, T_6 (120 V and 600 s) has the highest value and is regarded as the best treatment.

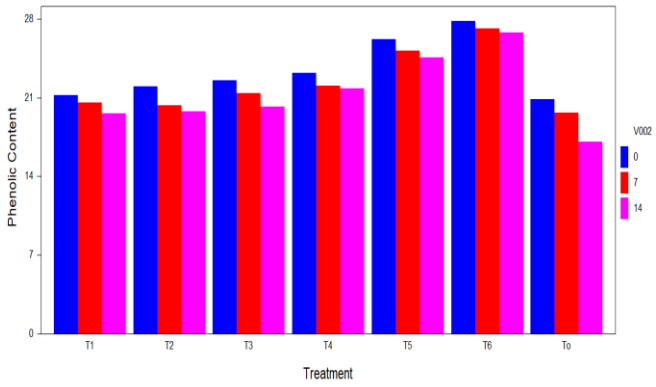

Figure 8. Effect of Ohmic Heating on Total Phenolic Content of Carrot and Orange Juice Blend.

***Total Plate Count*:** The minimum value of total plate count was observed in treatment T_6 at the 0 day (0.86±0.02 Log CFU/mL) followed by the treatment T_5 (0.98±0.05 Log CFU/mL). Duration of days also indicated the overall increasing trend for TPC. The highest recorded TPC value was observed at day 14 (5.93±0.06 Log CFU/mL), whereas the value at day 7 was slightly lower (5.85±0.15 Log CFU/mL). So, the lowest value of TPC for treatment T_6 (120V and 600s) at 0 day indicated that it was the best treatment to reduce the microbial count of carrot and orange juice blend.

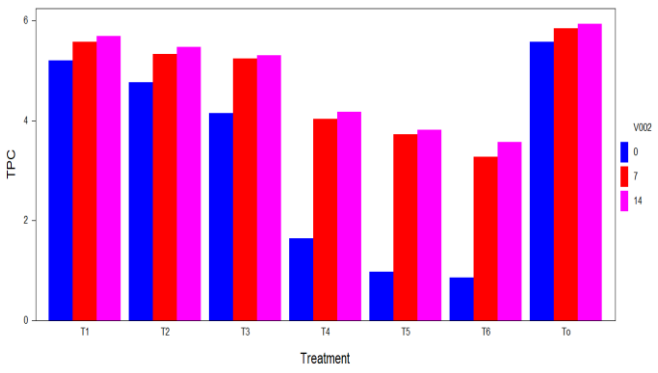

Figure 9. Effect of Ohmic Heating on TPC of Carrot and Orange Juice Blend.

Table 4. Means for Color of Carrot and Orange Juice Blend.

	Treatments	Storage Intervals (Days)			
		0 days	7 days	14 days	Means
Total Phenolic Content	T_0	20.89±0.22	19.67±0.19	17.08±0.1	$19.213±1.69^{G}$
	T_1	21.22±0.14	20.58±0.06	19.62±0.11	$20.473±0.70^{F}$
	T_2	21.98±0.15	20.35±0.23	19.78±0.08	$20.703±0.99^{E}$
	T_3	22.53±0.16	21.42±0.06	20.21±0.05	$21.387±1.00^{D}$
	T_4	23.19±0.17	22.08±0.07	21.83±0.2	$22.367±0.64^{C}$
	T_5	26.22±0.04	25.19±0.12	24.57±0.22	$25.327±0.73^{B}$
	T_6	27.81±0.24	27.16±0.19	26.83±0.07	$27.267±0.45^{A}$
	Means	$23.41±2.62^{A}$	$22.35±2.78^{B}$	$21.42±3.30^{C}$	
Total Plate Count	T_0	5.57±0.17	5.85±0.15	5.93±0.06	$5.783±0.20^{A}$
	T_1	5.20±0.30	5.57±0.25	5.69±0.12	$5.487±0.30^{B}$
	T_2	4.77±0.26	5.33±0.02	5.47±0.18	$5.190±0.35^{C}$
	T_3	4.15±0.04	5.24±0.08	5.31±0.02	$4.900±0.56^{D}$
	T_4	1.64±0.05	4.03±0.1	4.17±0.11	$3.280±1.23^{E}$
	T_5	0.98±0.05	3.73±0.05	3.81±0.02	$2.840±1.39^{F}$
	T_6	0.86±0.02	3.28±0.12	3.57±0.19	$2.570±1.29^{G}$
	Means	$3.31±2.07^{C}$	$4.72±1.01^{B}$	$4.85±0.97^{A}$	
Total Coliform Count	T_0	6.15±0.3	6.47±0.09	6.98±0.07	$6.533±0.39^{A}$
	T_1	6.04±0.52	6.21±0.12	6.35±0.17	$6.200±0.31^{B}$
	T_2	5.98±0.34	6.09±0.06	6.17±0.11	$6.080±0.19^{BC}$
	T_3	5.43±0.26	5.97±0.04	6.03±0.09	$5.810±0.31^{C}$
	T_4	5.14±0.39	5.39±0.22	5.54±0.18	$5.357±0.29^{D}$
	T_5	4.95±0.08	5.09±0.1	5.2±0.02	$5.080±0.12^{DE}$
	T_6	4.77±0.15	4.79±0.17	4.82±0.06	$4.793±0.11^{E}$
	Means	$5.49±0.56^{C}$	$5.72±0.62^{B}$	$5.87±0.73^{A}$	

***Total Coliform Count*:** The maximum value of TCC had noticed in treatment T_0 (6.98±0.07 Log CFU/mL) at 14th day. The lowest observed value was noted for treatment T_6 (4.77±0.15 Log CFU/mL) on day 0, with a similar value observed for T_6 (4.79±0.17 Log CFU/mL) on the 7th day. Duration of days indicated the increasing trend while treatment with different time and voltage indicates the decreasing trend (6.15±0.3-4.77±0.15 Log CFU/mL). So, the treatment T_6 (120V and 600s) at 0 day (4.77±0.15 Log CFU/mL) was considered as the best treatment because minimal growth was observed.

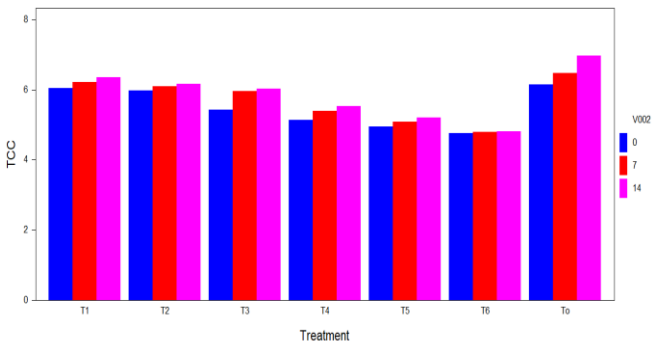

Figure 20. Effect of Ohmic Heating on TCC of Carrot and Orange Juice Blend.

***Sensory Evaluation*:** Sensory analysis of carrot and orange juice blend treated with ohmic heating is a scientific discipline that applies principles of experimental design and statistical analysis to the use of human senses for the purposes of evaluating product. The maximum flavor score was noticed in treatment T_5 (8.9±0.4) at 0 days and then for treatment T_6 (8.7±0.5) at 0 days. The minimum flavor score after 14 days was observed in the control treatment T_0 (4.6±0.5). The maximum overall acceptability score was noticed in treatment T_3 (8.8±0.2) at 0 days and then for treatment T_5 (8.6±0.1) at 0 days. The minimum overall acceptability score after 14 days was observed in the control treatment T_0 (3.7±0.9).The maximum aroma score was noticed in treatment T_5 (8.9±0.7) at 0 days and then for treatment T_6 (8.7±0.5) at 0 days. The minimum aroma score after 14 days was observed in the control treatment T_0 (3.9±0.2).The maximum appearance score was noticed in control treatment T_0 (7.1±0.8) at 0 days, followed by treatment T_4 (7.8±0.4) at 0 days. The minimum appearance score after 14 days was observed in the control treatment T_0 (3.5±0.7. T_6 (120 V and 600 s) had the least decline in all the sensory parameters and is considered the best treatment because it preserved the quality of the juice blend.

Table 5. Means for Sensory Evaluation of Carrot and Orange Juice Blend.

Treatment	Day	Appearance	Flavor	Aroma	Overall acceptability
T_0	0	7.1±0.8	8.1±0.7	8.2±0.8	8.2±1.1
	7	5.2±0.6	6.4±0.8	5.1±0.1	5.9±0.2
	14	3.5±0.7	4.6±0.5	3.9±0.2	3.7±0.9
T_1	0	7.3±0.4	8.6±0.4	8.5±0.4	8.7±1.0
	7	5.7±0.5	6.1±0.2	5.7±0.3	6.6±0.6
	14	4.1±1.4	4.9±0.1	4.5±0.5	4.2±0.7
T_2	0	7.7±0.5	8.3±0.5	8.6±0.3	8.4±0.4
	7	5.4±0.7	6.5±0.7	6.3±0.7	6.5±1.2
	14	4.0±1.2	5.1±0.7	5.3±0.3	4.9±0.5
T_3	0	7.5±0.8	8.6±0.4	8.3±0.1	8.8±0.2
	7	6.3±0.4	6.9±1.3	6.9±0.6	6.8±0.5
	14	4.8±0.6	6.1±0.3	5.8±0.7	5.5±0.1
T_4	0	7.8±0.4	8.5±1.4	8.5±0.2	8.2±0.3
	7	6.1±0.2	7.3±0.6	7.5±0.9	6.9±1.5
	14	5.1±0.5	5.9±0.6	5.9±0.1	6.1±0.2
T_5	0	7.4±0.8	8.9±0.4	8.9±0.7	8.6±0.1
	7	6.5±0.1	7.7±0.4	7.3±0.2	7.3±0.9
	14	5.6±0.1	6.9±1.1	6.4±0.9	6.9±0.4
T_6	0	7.2±0.5	8.7±0.5	8.7±0.5	8.5±0.2
	7	6.9±0.7	8.0±0.3	7.7±0.5	7.8±0.3
	14	6.1±0.9	7.5±0.8	6.6±0.2	7.1±0.3

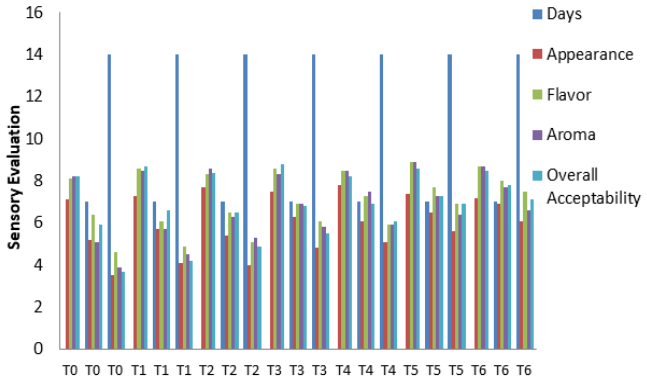

Figure 11. Sensory Evaluation of Carrot and Orange Juice Blend.

DISCUSSION

Ohmic heating treatment significantly impacted physicochemical properties (pH, TTA, TSS, color, vitamin C and phenolic content) of juice blend enhancing and maintaining its quality. Microbial analysis (TPC and TCC) was also conducted to assess safety attributes. Sensory evaluation of ohmically treated juice samples was done to determine which treated juice sample had the best consumer acceptability.

The ohmically heated carrot and orange juice blend was subjected to physicochemical analysis. The results of the study for pH of carrot and orange juice blend were in line with those found by Fadavi et al. (2018) evaluated how ohmic heating affected tomato concentrate quality. There were three different voltages applied 40, 50, and 60 V or voltage gradients 10.5, 13.2, and 15.8 V/cm with 50 Hz. The results demonstrated that raising the voltage caused the pH of tomato juice to drop. The results of TTA are in line with Yildiz et al. (2014)compared to the effects of ohmic heating and conventional heating on the consistency and quality of pomegranate juice under varying voltage gradients. Pomegranate juice samples were ohmically heated from 20°C to 90°C using voltage gradients of 10-40 V/cm at 50 Hz. The samples were held at 90°C for 0, 3, 6, 9, or 12 minutes. The results indicated that titratable acidity of pomegranate juice increased by using ohmic heating. The results for color of juice blend were in line with Makroo et al. (2017)compared the efficacy of hot-water (HW) and ohmic (OH) treatments in inactivating polyphenol oxidase (PPO) in watermelon juice and to evaluate the impact of these treatments on the color of the juice. Watermelon juice was treated at 90 °C using HW and OH methods for durations of 15, 30, 45, and 60 seconds. The PPO activity, total phenols, lycopene content, and color changes (ΔE and hue angle) were measured post-treatment. Total color change (ΔE) during OH treatment was less than that observed with HW treatment. The hue angle increased at a higher rate in HW treatment compared to OH treatment. The results for Vitamin C of juice blend coincide with results reported by Athmaselviet al. (2017) who evaluated the influence of temperature, voltage gradient, and electrode type on vitamin C degradation in tropical fruit pulps (papaya,

sapota, and guava) during ohmic heating. Tropical fruit pulps were ohmically heated using titanium and stainless-steel electrodes at temperatures between 70°C to 90°C for 15 minutes with varying voltage gradients. Ohmic heating led to ascorbic acid degradation of 9.72 to 41.56% in papaya, 12.46 to 58.21% in sapota, and 10.79 to 20.66% in guava pulps.

The ohmically heated carrot and orange juice blend was subjected to phytochemical analysis. The results for Total phenolic content are coinciding with the results of Abedelmaksoud et al. (2018) who investigated the effect of ohmic heating (OH) parameters on the inactivation of polyphenoloxidase (PPO) and pectinmethylesterase (PME) in not-from-concentrate (NFC) mango juice. Ohmic heating of 40 V, 80°C and holding time for 60 sec was used. The total phenolic content in mango juice increased by 8% for ohmic heating (OH) treated samples; while it increased by 5% for conventional heating (CH) treated samples.

Microbial analysis was performed on the carrot and orange juice blend treated with ohmic heating. The results for the Total plate count of juice blend were in line with Parmar et al. (2018) who investigated the impact of ohmic heating on physicochemical, rheological, sensorial and microbiological properties during the concentration of cow milk, buffalo milk and mixed milk compared to conventional evaporation. Cow milk, buffalo milk and mixed milk were concentrated using ohmic heating with a constant voltage gradient of 13 V/cm over a 75-minute period, collecting samples at 15-minute intervals for analysis. Ohmic heating led to a drastic reduction in microbial counts (3-4 logs), indicating improved microbial safety and extended shelf-life potential of the treated milk products. The results for total coliform count of juice blend were in line with Rodríguez et al. (2021) examined the effects of ohmic heating (OH) on carrot juice, it was found that OH treatment significantly reduced total coliform counts (TCC) to levels below the quantification and detection thresholds, confirming effective pasteurization. Over a 60-day storage period at 4 °C, TCC remained below these thresholds in OH-treated juice, demonstrating sustained microbial stability. This finding underscores the efficacy of ohmic heating in maintaining the microbiological quality of carrot juice over extended storage periods, ensuring its safety and extending its shelf life.

The ohmically heated carrot and orange juice blend was then subjected to sensory analysis. The results for sensory evaluation of juice blend were coinciding with Alcántara-Zavala et al. (2019) *who examined* the shelf life of pulque while preserving its physicochemical, probiotic, and sensory properties using ohmic heating (OH) compared to conventional pasteurization. Pulque was processed using ohmic heating (OH) at temperatures of 65°C (5 and 7 minutes) and 70°C (3 and 5 minutes). Conventional pasteurization (63°C, 30 minutes) was used as a control. Pulque treated with OH at 65°C for 5-7 minutes, and at 70°C for 5 minutes, showed superior sensory acceptance compared to conventional pasteurization.

***Conclusion*:** This research presented a detailed examination of the impact of ohmic heating on the quality and stability of a carrot and orange juice blend. The study successfully demonstrated that ohmic heating is a promising method that significantly enhances and maintains the physicochemical, phytochemical, microbial and sensory attributes of the juice blend. This suggests that ohmic heating can extend the shelf life of juice blends while maintaining their nutritional quality. The ohmic heating treatment not only improves the texture and consistency of the juice but also balances the flavors, making the blend more palatable and enjoyable. This insight gained from this research contributes to understand the benefits of blending and the application of ohmic heating in juice processing. In a nutshell, this study demonstrated the potential of ohmic heating as an advanced alternative to conventional heating methods, offering a more efficient and nutrient-preserving approach to juice pasteurization.

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***CRediT author statement*:** Esha Afzal and Ali Hassan designed the study plan. Esha Afzal, Maryam Tufail Chaudhary and Fatima Waheed performed all the analysis and recorded the data. Ali Hassan, Fatima Waheed and Maryam Tufail Chaudhary analyzed the results. Esha Afzal wrote the original draft. All the authors critically reviewed the final manuscript and approved it.

***Conflict of Interest*:** The authors have declared no conflict of interest.

***Ethical Statement*:** This study did not involve any experiments with humans or animals requiring ethical approval.

***Availability of data*:** All the data and materials belong to authors and will be produced when required.

***Consent to Participate*:** All authors participated in this research study.

***Informed consent*:** N/A

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***SDGs addressed*:** Zero Hunger, Good Health & Well-Being, Affordable & Clean Energy, Industry Innovation & Infrastructure, Responsible Consumption & Production, Climate Action**.**

Policy referred: Pakistan National Food Security Policy; National Nutrition Policy; Pakistan Standards & Quality Control Regulations (PSQCA); FAO Food Safety & Quality Guidelines; Codex Alimentarius Standards.

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REFERENCES

Achir, N., Mayer, C. D., Hadjal, T., Madani, K., Pain, J. P., & Dornier, M. (2016). Pasteurization of citrus juices with ohmic heating to preserve the carotenoid profile. *Innovative Food Science and Emerging Technologies*, *33*, *397–404*. https://doi.org/10.1016/j.ifset.2015.11.002

Abedelmaksoud, T., Mohsen, S. M., Olesen, L. D., Elnikeety, M. M., & Feyissa, A. H. (2018). Effect of ohmic heating parameters on inactivation of enzymes and quality of not-from-concentrate mango juice. *Asian Journal of Scientific Research*, *11*, *383–392*. https://doi.org/10.3923/ajsr.2018.383.392

Adubofuor, J., Amoah, I., & Agyekum, P. B. (2016). Physicochemical properties of pumpkin fruit pulp and sensory evaluation of pumpkin–pineapple juice blends. *American Journal of Food Science and Technology*, *4*, *89–96*. https://doi.org/10.12691/ajfst-4-4-1

Alcántara, Z. A. E., Cárdenas, D. F. J., Sánchez, M. E., Tapia, A. J. A., Medrano, A. S. M., & Flores, M. H. E. (2019). Application of ohmic heating to extend shelf life and retain the physicochemical, microbiological, and sensory properties of pulque. *Food and Bioproducts Processing*, *118*, *139–148*. https://doi.org/10.1016/j.fbp.2019.09.007

Aneja, K. R., Dhiman, R., Aggarwal, N. K., Kumar, V., & Kaur, M. (2014). Microbes associated with freshly prepared juices of citrus and carrots. *International Journal of Food Science*, *2014*, *7–21*. https://doi.org/10.1155/2014/408085

Athmaselvi, K. A., Kumar, C., & Poojitha, P. P. (2017). Influence of temperature, voltage gradient, and electrode on ascorbic acid degradation kinetics during ohmic heating of tropical fruit pulp. *Journal of Food Measurement and Characterization*, *11*, *144–155*. https://doi.org/10.1007/s11694-016-9381-5

AOAC (Association of Official Analytical Chemists). (2023). *Official Method of Analysis of AOAC International* (22nd ed.). Oxford University Press.

Asghar, U., Nadeem, M., Nelofer, R., Mahar, S., Syed, Q., & Irfan, M. (2018). Microbiological assessment of fresh juices vended in different areas of Lahore city. *Electronic Journal of Biology*, *14*, *106–110*.

Doan, N. K., Lai, D. Q., & Le, T. K. P. (2023). Ohmic heating: Current and future application in juice processing. *Food Reviews International*, *39*, *6908–6933*. https://doi.org/10.1080/87559129.2022.2126855

Esteve, M. J., & Frigola, A. (2008). Effects of thermal and non-thermal processing on vitamin C, carotenoids, phenolic compounds, and total antioxidant capacity in orange juice. *Tree and Forestry Science Biotechnology*, *2*, *128–134*.

Fadavi, A., Yousefi, S., Darvishi, H., & Mirsaeedghazi, H. (2018). Comparative study of ohmic-vacuum, ohmic, and conventional-vacuum heating methods on the quality of tomato concentrate. *Innovative Food Science and Emerging Technologies*, *47*, *225–230*. https://doi.org/10.1016/j.ifset.2018.03.004

Hussein, A., Hegazy, N., & Kamel, M. (2022). Production of nutritious juice blends containing bioactive healthy compounds. *Egyptian Journal of Chemistry*, *65*, *333–339*. https://dx.doi.org/10.21608/ejchem.2021.87808.4238

Jan, B., Shams, R., Rizvi, Q., & Manzoor, A. (2021). Ohmic heating technology for food processing: A review of recent developments. *Journal of Postharvest Technology*, *9*, *20–34*.

Karangwa, E., Hayat, K., Rao, L., Nishimiyimana, D. S., Foh, M. B., Li, L., Natwali, J., Raymond, L. V., Xia, S., & Zhang, X. (2012). Improving blended carrot–orange juice quality by the addition of cyclodextrins during enzymatic clarification. *Food and Bioprocess Technology*, *5*, *2612–2617*. https://doi.org/10.1007/s11947-011-0557-z

Makroo, H., Saxena, J., Rastogi, N., & Srivastava, B. (2017). Ohmic heating assisted polyphenol oxidase inactivation of watermelon juice: Effect on pH, lycopene, total phenolic content, and color. *Journal of Food Processing and Preservation*, *41*, *13271–13280*. https://doi.org/10.1111/jfpp.13271

Parmar, P., Singh, A. K., Meena, G. S., Borad, S., & Raju, P. (2018). Application of ohmic heating for concentration of milk. *Journal of Food Science and Technology*, *55*, *4956–4963*. https://doi.org/10.1007/s13197-018-3431-4

Potter, A. S., Foroudi, S., Stamatikos, A., Patil, B. S., & Deyhim, F. (2011). Drinking carrot juice increases total antioxidant status and decreases lipid peroxidation in adults. *Nutrition Journal*, *10*, *1–6*. http://www.nutritionj.com/content/10/1/96

Rawal, P., Dudeja, I., Singh, A. P., Purewal, S. S., Kaur, A., & Swamy, C. T. (2023). Orange. In *Recent Advances in Citrus Fruits* (pp. 69–98).

Rodríguez, L. M. N., Arias, R., Soteras, T., Sancho, A., Pesquero, N., Rossetti, L., & Szerman, N. (2021). Comparison of the quality attributes of carrot juice pasteurized by ohmic heating and conventional heat treatment. *LWT – Food Science and Technology*, *145*, *111255–111267*. https://doi.org/10.1016/j.lwt.2021.111255

Singh, M. N., Srivastava, R., & Yadav, I. (2021). Study of different varieties of carrot and its benefits for human health: A review. *Journal of Pharmacognosy and Phytochemistry*, *10*, *1293–1299*. https://doi.org/10.22271/phyto.2021.v10.i1r.13529

Yildiz, H., & Guven, E. (2014). Industrial applications and potential use of ohmic heating for fluid foods. *Bulgarian Chemical Communications*, *46*, *98–102*. http://bcc.bas.bg/BCC_Volumes/Volume_46_Special_B_2014/BCC-46-B-98-102.pdf